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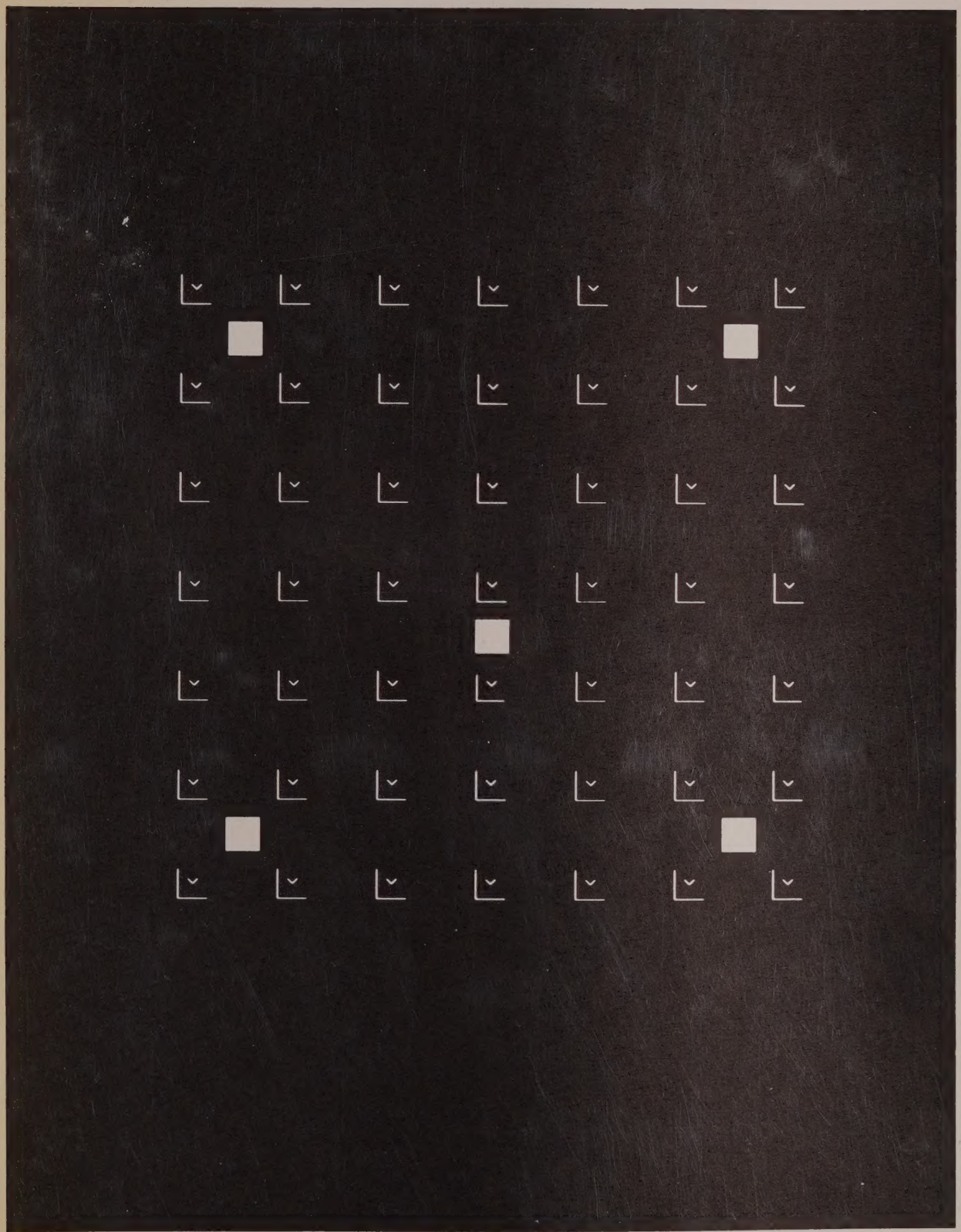

GS-1000

PRECISION DISPLAY MEASUREMENT SYSTEM

EG&G GAMMA SCIENTIFIC

GS-1000
AUTOMATIC
PRECISION DISPLAY MEASUREMENT SYSTEM

BY

EG&G GAMMA SCIENTIFIC, INC.

SEPTEMBER 1, 1984

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Introduction

The EG&G Gamma Scientific GS-1000 is an automatic, computer controlled system for analyzing spatial and spectral characteristics of cathode ray tubes, computer terminals and television receivers and monitors. Its speed of measurement makes possible production line measurements.

It measures deflection linearity, luminance, spot size and astigmatism, at any number of desired locations (typically 10 to 50) within the display field. In addition, color measurement capability may be added.

Traditional techniques for these measurements depend on scanning photometric microscopes and microspectroradiometers. These instruments have to be mounted on X Y mechanisms in order to make measurements at various locations on the face of the CRT. Because of the appreciable time to move the measuring head from one location to another, this approach has severe limitations for production testing. In addition, mechanical and focusing requirements dictate substantial expense and skilled operator time.

It is the purpose of this document to describe a new, advanced technique for making these measurements automatically on CRT displays using an operator of minimum skill and minimum operator time.

The Basic Technique

The technique used in the GS-1000 System, shown in Figure 1, begins with a precision telescope which is focused on and which views the whole face of the CRT under measurement. This part of the discussion relates to measurements on monochrome CRT's.

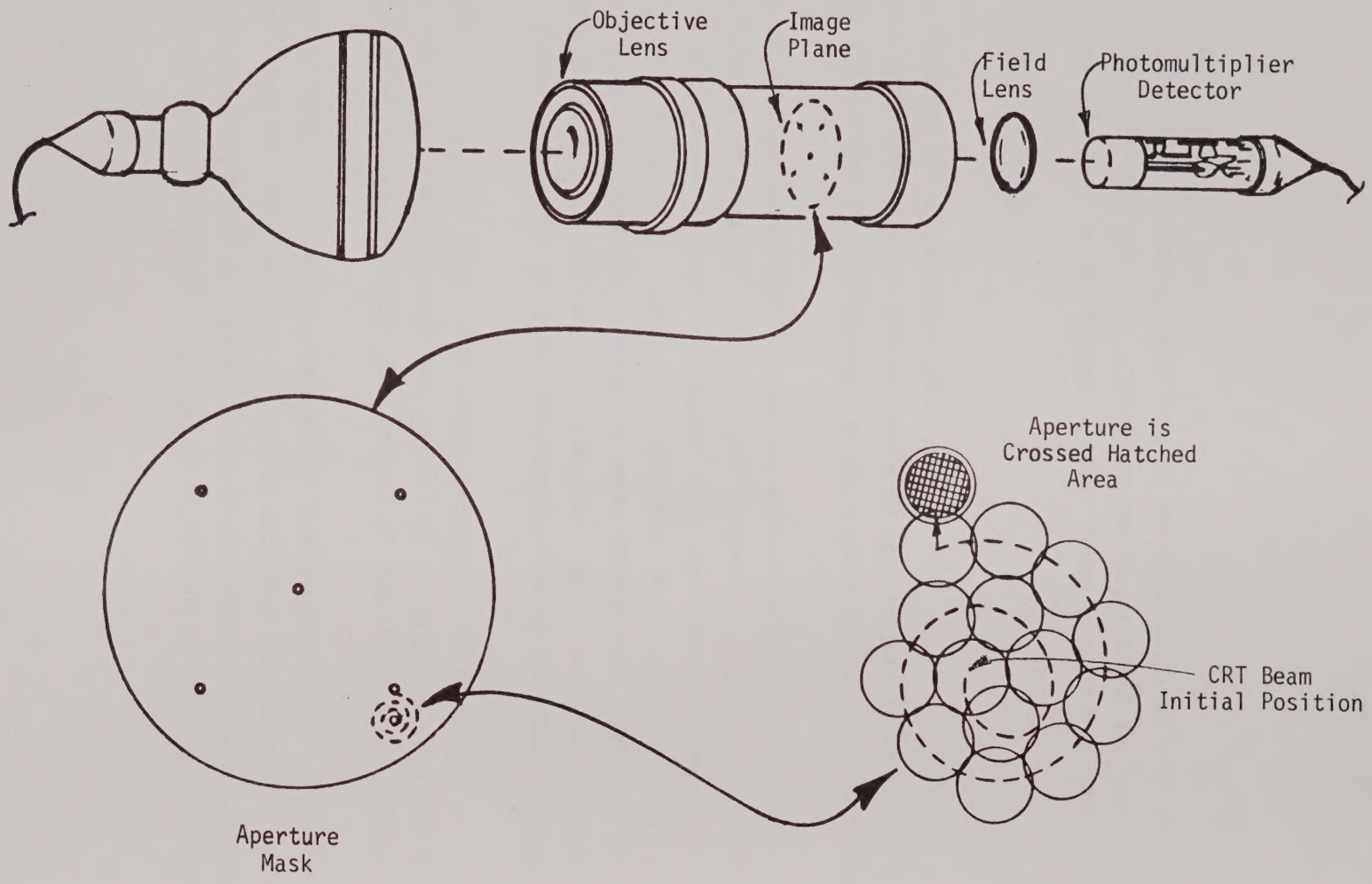

Objective Lens
Image Plane
Field Lens
Photomultiplier Detector
Aperture is Crossed Hatched Area
CRT Beam Initial Position
Aperture Mask

Figure 1

An opaque aperture mask is placed in the telescope's image plane. The mask has a number of very small apertures. Each aperture is at a location corresponding to a point on the face of the CRT where a measurement is desired to be made. The electron beam of the CRT is moved to one of these locations. With proper alignment of the CRT and focusing of the telescope, the image of the illuminated phosphor spot produced by the electron beam falls on the corresponding aperture in the mask of the telescope. Light passes thru the aperture and a field lens to a sensitive photomultiplier detector behind the mask. The detector, in turn, converts the light from the image into an electrical output signal.

What are the advantages of this technique? They may be summarized as follows:

1. Completely Non-Mechanical

   Nothing moves but the beam.

2. Fast

   Deflection linearity, luminance, spot size and astigmatism measurements in less than 10 seconds per location.

3. Accurate/High Resolution

   a) Capable of measuring dimensions to better than 1/10,000 of frame size.

   b) All output data is digital.

4. Flexible

   a) All output data is digital.

   b) Output data is reduced to absolute units.

   c) Output data may be stored, transmitted, or analyzed (MTF) digitally.

   d) Test routines may be changed by changing software.

5. Versatile

   Same system can measure

   a) Different size CRTs

   b) Projection systems

   c) Heads-up displays.

6. Objective

   Removes human errors, judgment and skill from the data.

7. Labor Saving

   Measurements are under computer software control. Only operator time is loading and unloading unit under test.

8. Rugged

   Sturdy design and no moving parts give system extremely long, trouble-free life.

9. Capable of Color Measurement

   Color measurement may be added as an option.

Deflection Linearity Measurement

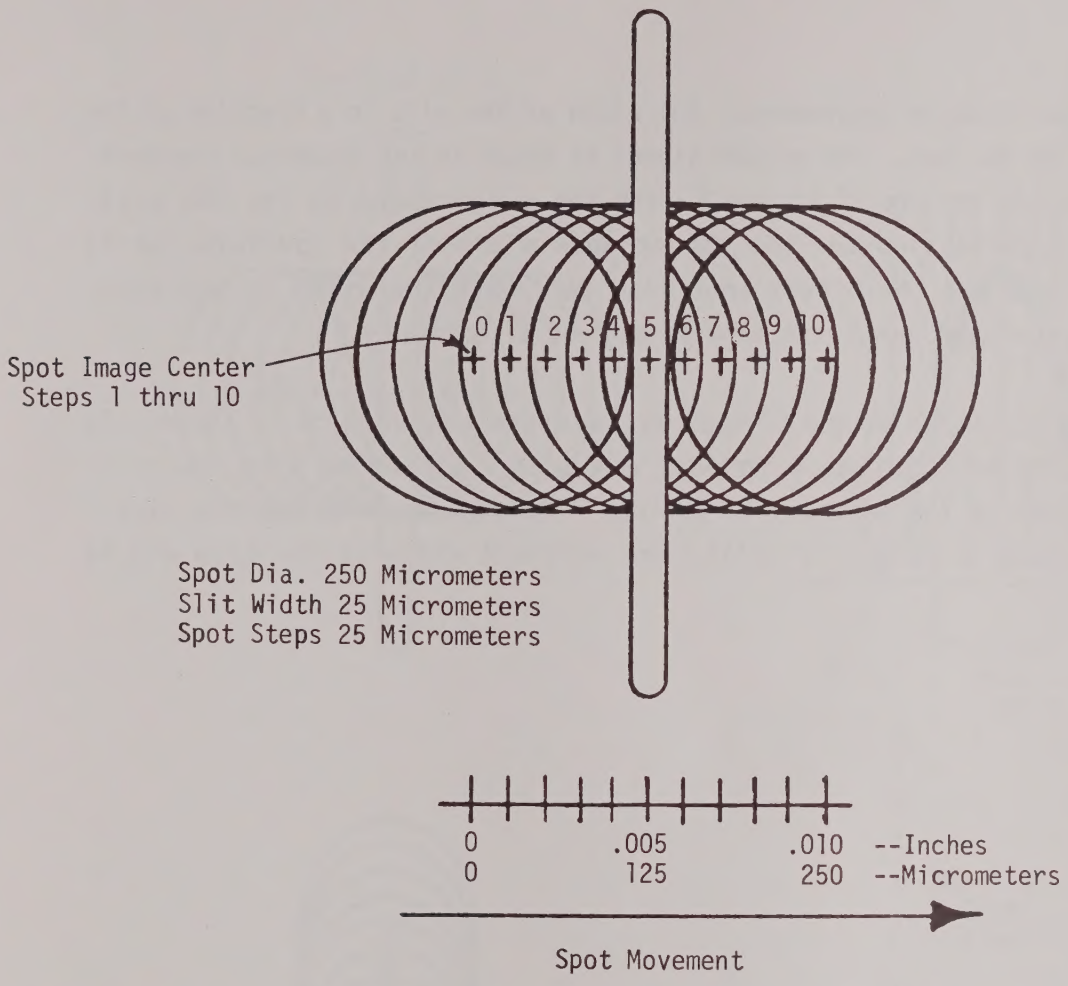
If the image of the spot does not fall on the aperture, no light will be detected. The electron beam may now be put into a search pattern, such as a spiral, until light is detected and then maximized. Under these conditions deflection parameters in the horizontal and vertical axes may be determined and compared to those for design center operation. Thus at that location, actual deflection position (linearity) performance of the CRT can be related to the design center performance and deflection distortion values can then be determined.

Up until now only one location on the CRT has been considered. Once one location's deviation from the design center location has been measured, other locations can be similarly characterized, one by one, until the whole CRT display field is mapped for deflection distortion or linearity.

Spot Size and Astigmatism Measurements

The spot size measurement is shown in Figure 2. Typical dimensions are included only for clarity. Here the CRT spot is scanned across a thin aperture. In the figure the beam is stepped across the aperture slit in

SPOT SIZE MEASUREMENT TECHNIQUE


Spot Image Center
Steps 1 thru 10
0 1 2 3 4 5 6 7 8 9 10
Spot Dia. 250 Micrometers
Slit Width 25 Micrometers
Spot Steps 25 Micrometers
0 .005 .010 --Inches
0 125 250 --Micrometers
Spot Movement

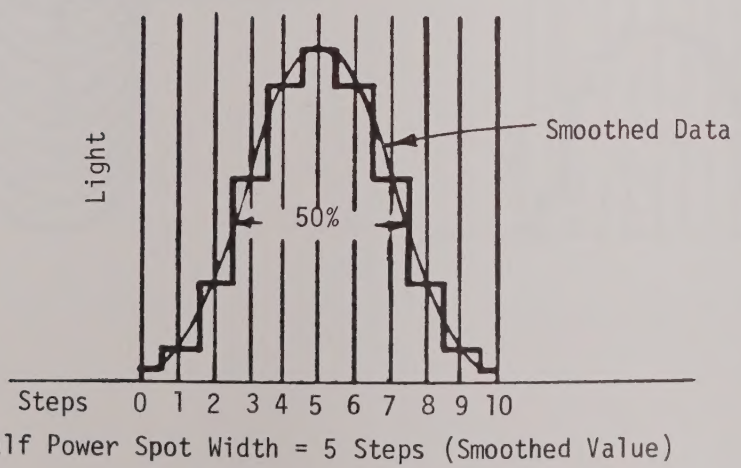


Figure 2

1/10th spot diameter increments. The width of the slit is a fraction of the diameter of the spot. The output signal is shown in the graphical representation at the bottom of Figure 2 with the measurement at the 50% power point. A correction for the appreciable width of the aperture can be applied then and the actual spot size derived. The width at any other percentage of peak power can also be derived if desired.

In Figure 3, the technique of spot astigmatism measurement is shown. By stepping the beam through a vertical slit with a horizontal scan, the horizontal width of the beam may be derived. Then by stepping the spot vertically through a horizontal slit, the vertical width of the beam may be measured.

SPOT ASTIGMATISM MEASUREMENT TECHNIQUE

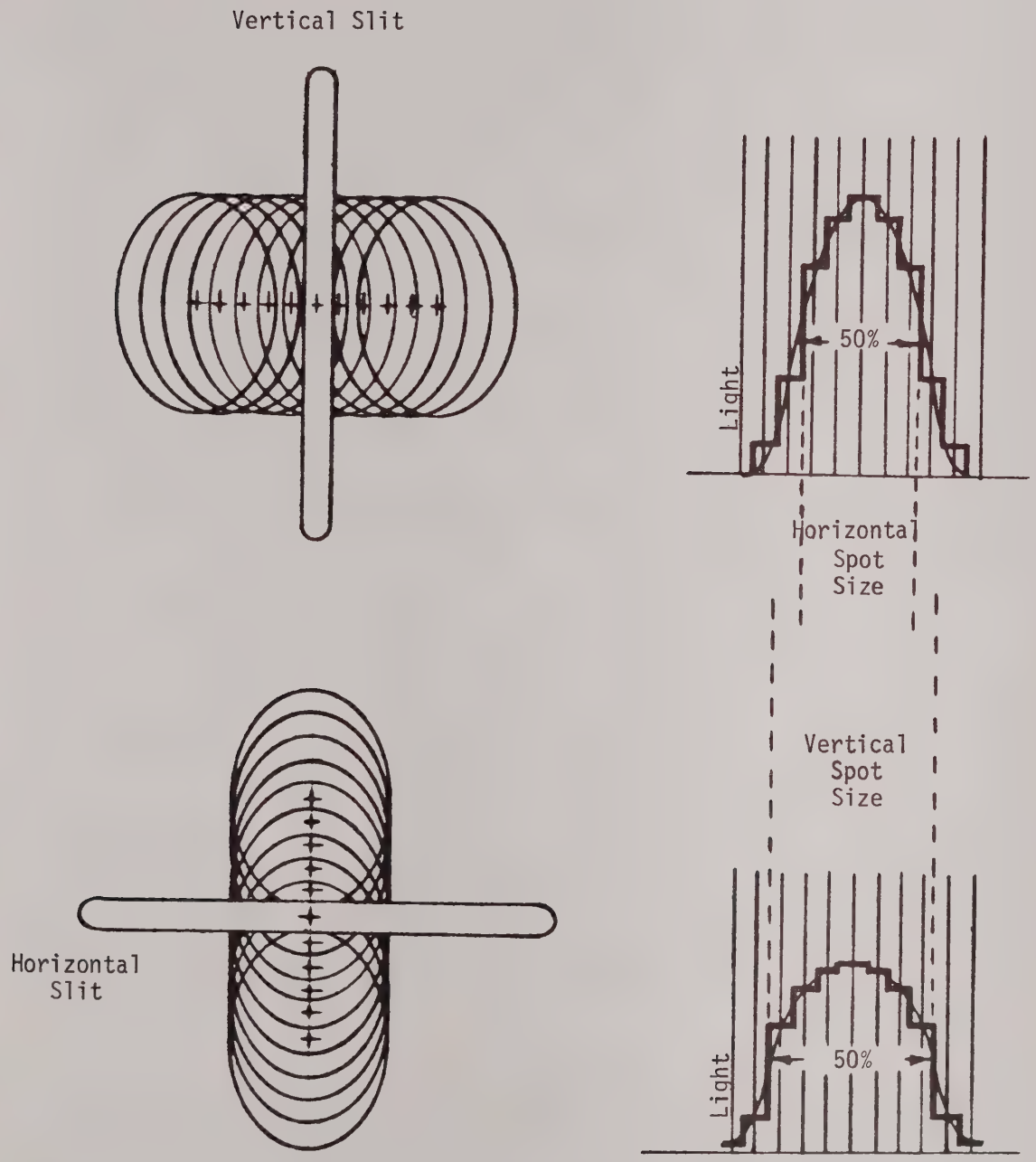


Figure 3

Combined Position and Spot Size Measurements

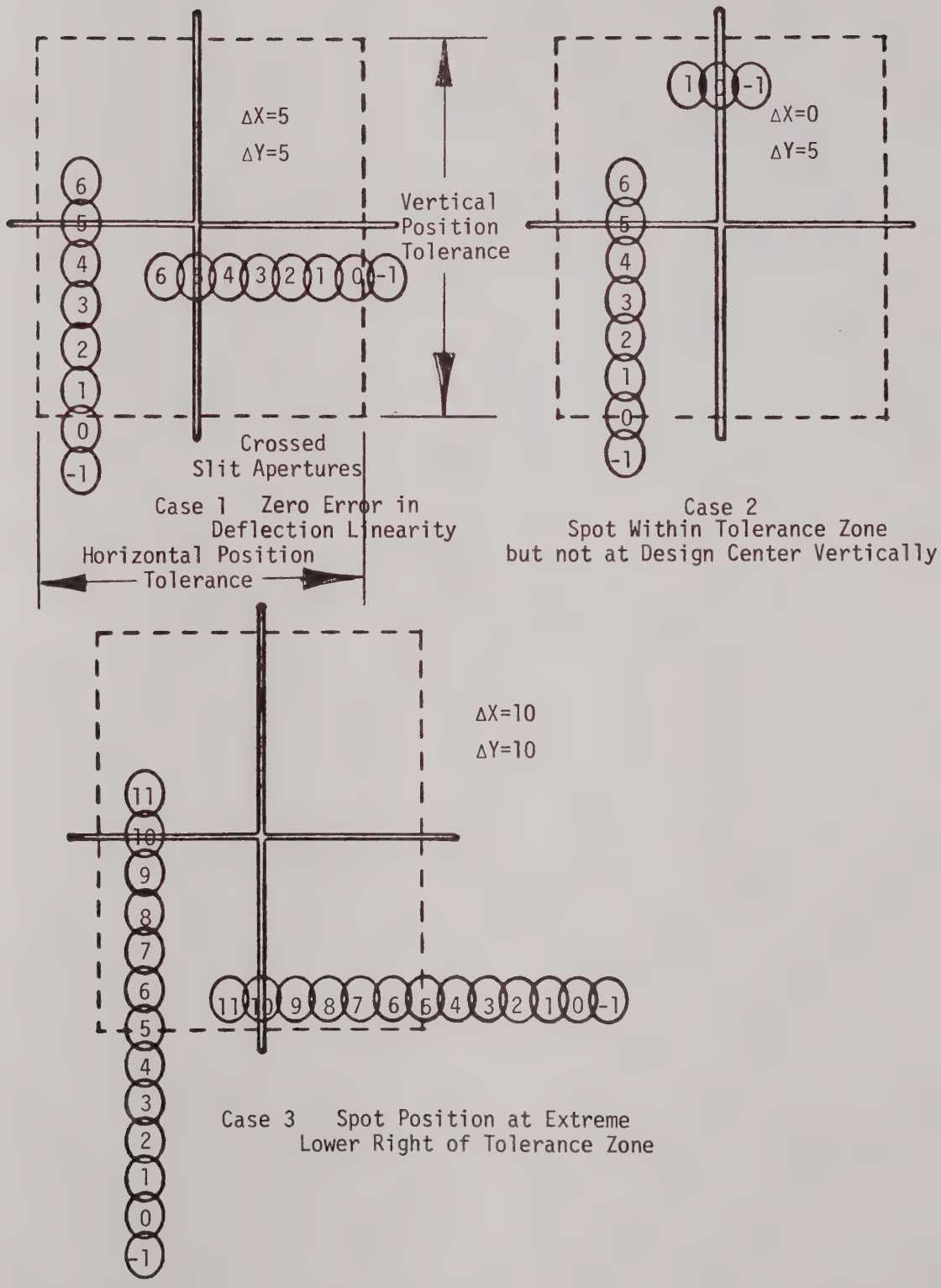
In Figure 4, a slit aperture in the form of a cross is used in making the measurements. This configuration allows both position and spot size measurements to be made with a single aperture. The dimensions of the cross are established by the tolerance assigned to the deflection non-linearity. As an example, in a CRT with 5" diameter face, the deflection linearity specification could be defined to be within 1% of the screen diameter at any given point on the screen. In this case, this would correspond to ±1.25mm (.050 in.) and the dimensions of the cross could be established as ±1.5mm (.060 in.) in each of the long dimensions and the slit width would be a fraction of the spot diameter as in Figures 1 and 2. Again, these apertures are for illustrative purposes and may be changed merely by changing aperture mask design.

In case 1 of Figure 4, the vertical scan at the left of the figure starts at the -1 position and moves upward. On the spot location No. 5, the light signal is detected. One further step, No. 6, is included so that the signal drops off again to insure that the beam has completely gone through the slit. In this case, we would assign that measurement a value of $\Delta X = 5$. Similarly in the horizontal scan in case 1, we start with -1 spot position to be sure it is outside the range of the slit. Light is detected at No. 5 and again one additional step is made to go through the maximum. Here we assign a ΔY of 5 to the measurement. Case 1 corresponds to a zero error in deflection linearity. In other words, it corresponds to a "design center" deflection condition.

Once these measurements have been made, the beam may be moved back to the No. 4 spot location in each scan, and is then stepped thru the aperture in much smaller increments as in Figures 2 and 3, discussed earlier, so that both spot size and astigmatism can also be determined.

Case 2 and 3 in Figure 4 shows what happens when the cathode ray tube spot is within tolerance but not at "design center". In case 2, at the -1 position in the horizontal scan no signal is detected but in the 0 position the signal is detected and in the 1 position no light is read. Thus ΔX becomes 0. But in case 2, in the vertical measurement, the system is similar to case 1 and the spot has to be moved to the No. 5 position for a light reading so we assign it a $\Delta Y = 5$ value. In case 3, we show the extreme condition where the spot is in the extreme lower right corner of the tolerance square. In this case, we have to move the beam to the 10 position, both in horizontal and vertical components and as a result, we come out with a measurement of $\Delta X = 10$ and $\Delta Y = 10$.

Thus, in this example, for any tube within manufacturing tolerance, the crossed slit aperture will permit the determination of the deflection error in a maximum of 11 steps in both horizontal and vertical axes.



Case 1 Zero Error in Deflection Linearity

Case 2
Spot Within Tolerance Zone
but not at Design Center Vertically

Case 3 Spot Position at Extreme Lower Right of Tolerance Zone

Figure 4

SPECIFIC APERTURE MASK DESIGN

A practical aperture mask is shown in Figure 5. In this design L's are used in place of the crosses in Figure 4. The L has the advantage that when the beam crosses either the vertical or horizontal part of the L and light is detected, there is no ambiguity as to where the other part of the slit is. For instance, in the case of illuminating the vertical member of the L, when light is detected the system knows the horizontal member is below and to the right. This eliminates any test to determine if the horizontal member is above or below the vertical member.

A 7 X 7 array has been chosen for several reasons. First, it provides enough data points throughout the display field to map geometric deflection distortions completely. As these distortions are relatively smooth functions, smoothing can be used to interconnect data points and provide accurate deflection correction factors anywhere within the display field.

Similarly, intensity, spot size and astigmatism data for any location can be completely derived from measurements at the 49 locations.

Another reason for the 7 X 7 array is that it provides an aperture in the center of the CRT, the location to which all other measurements are referenced, and yet it is one less than 8 so that only 3 binary bits are necessary to select any aperture along each axis.

Also shown in Figure 5 are five large square apertures or windows placed between the L slit apertures in the extreme corners, with the fifth near the center of the field. These are included for raster luminance and color measurements. If it is desired to measure luminance under any specific drive condition, the beam under the specified condition can be used to scan only one of these apertures at a time. In the case of a full raster dis-

DETAILS OF GS-1000 APERTURE MASK

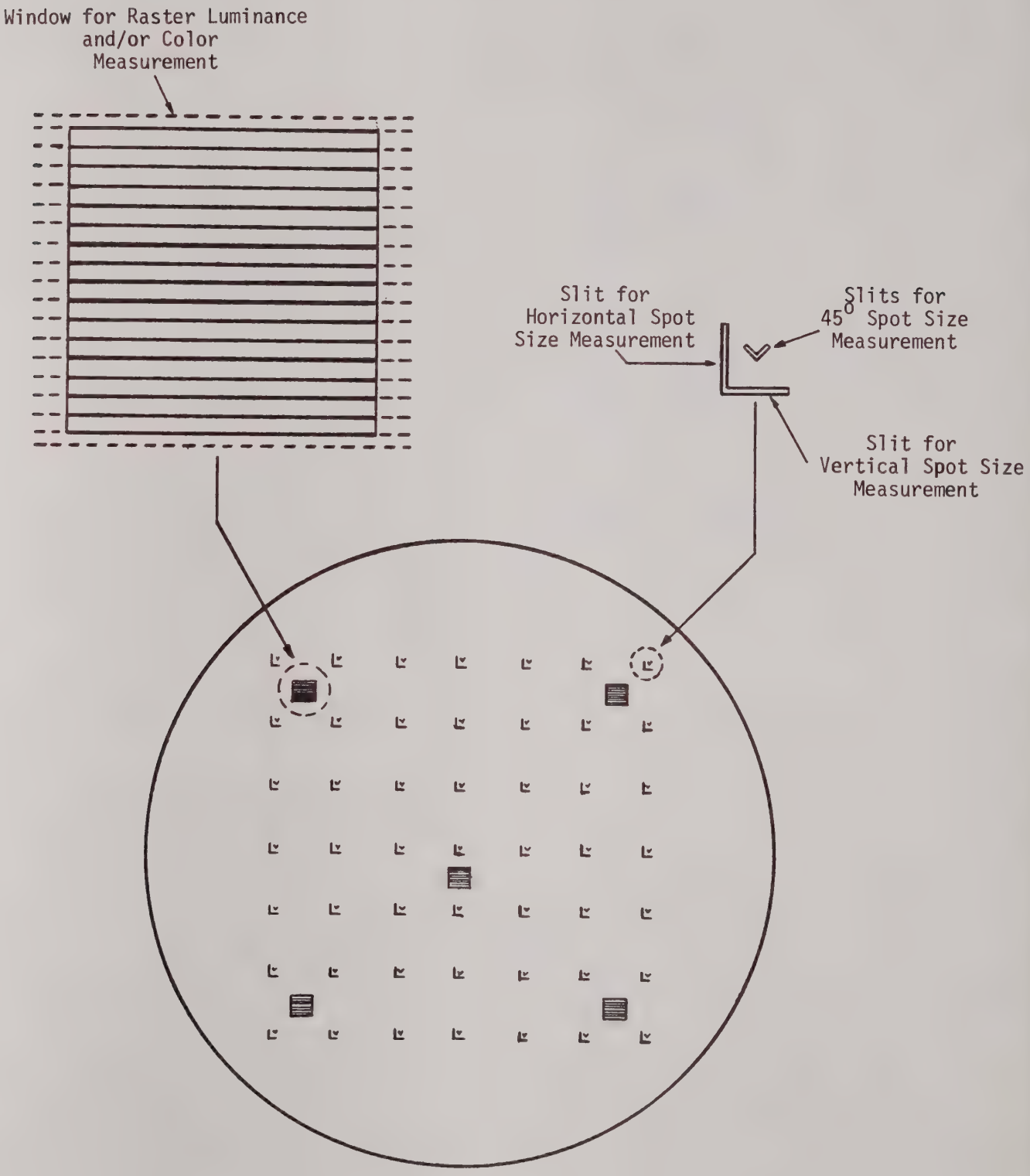

Window for Raster Luminance and/or Color Measurement
Slit for Horizontal Spot Size Measurement
Slits for 45° Spot Size Measurement
Slit for Vertical Spot Size Measurement

Figure 5

play, the beam is turned on just before getting to one of these apertures and turned off just after leaving it. By repeating this on adjacent scans, only the square aperture is illuminated and the rest of the display field is dark. By calibrating each square aperture separately with a suitable extended area (luminance) calibrated source, a factor can be developed for each window relating the photomultiplier detector's output relative to the absolute value of the source in terms of luminance. Then when measuring the CRT under test, its output can be compared to the detectors' response to the calibrated source and a ratio of the two values can be derived. Then by multiplying by the appropriate calibrating factor, the luminance of the CRT at that location may be calculated.

Figure 6 shows typical dimensions for one aperture. These dimensions relate to the aperture mask itself which may be up to 7.5cm (3") in diameter and will be modified by the demagnification or magnification of the objective lens.

The small V in the middle of the L has been added in case spot diameter measurements at 45^{o} to the horizontal and vertical axes are desired.

ENLARGED VIEW OF ONE SET OF APERTURES

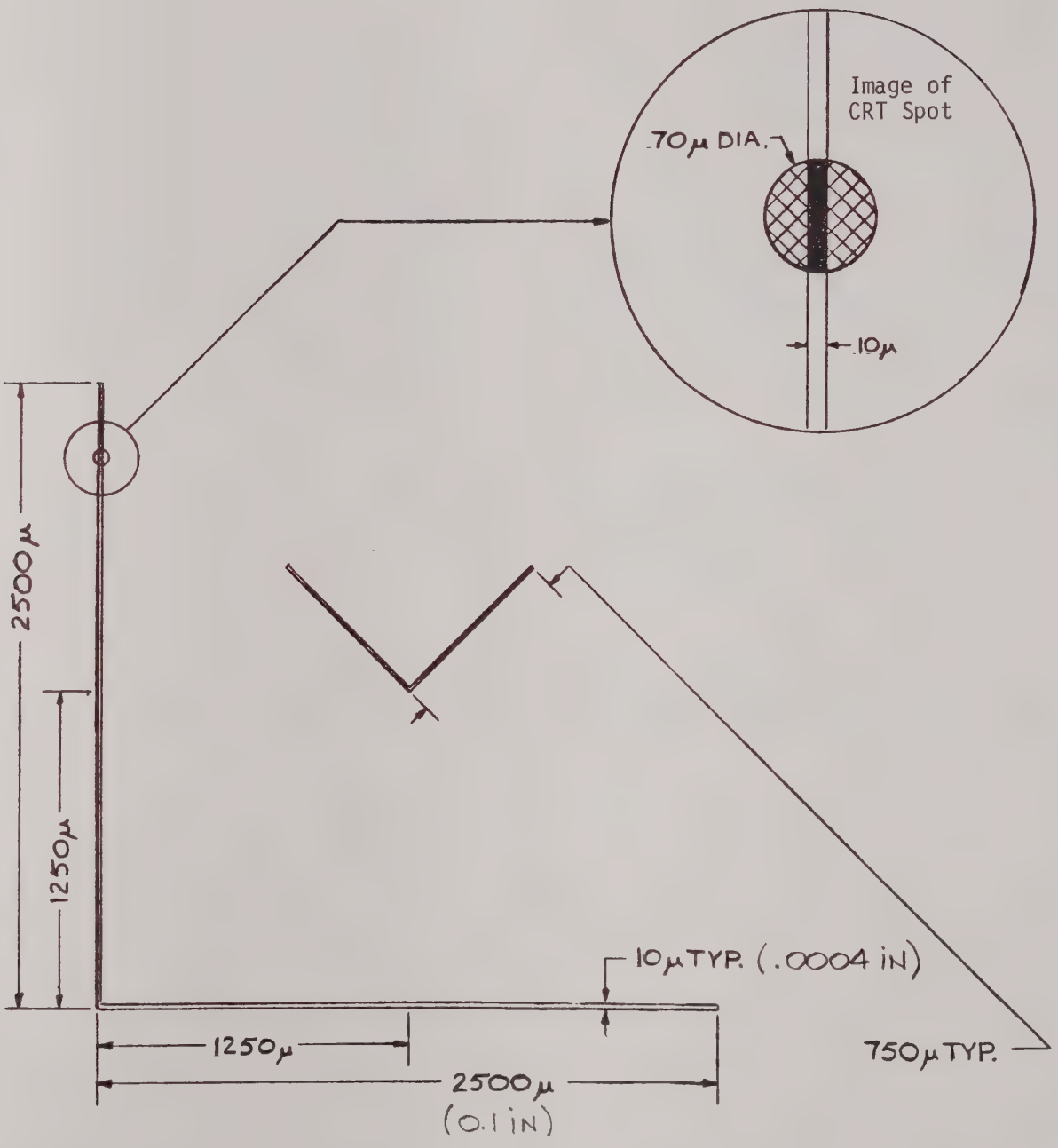


Figure 6

SPATIAL MEASUREMENT HARDWARE CONFIGURATION

The basic hardware configuration of the GS-1000 Precision Telescope is shown in Figure 7. This optical schematic shows the main objective focused at infinity with a supplemental lens added for measuring a specific size CRT. Other supplementary lenses with different focal lengths can be substituted for measurement of other size CRT's.

A back-up mask behind the precision aperture mask eliminates stray light from pinholes in the main mask.

Two Fresnel field lenses focus the entrance pupil of the objective lens on the photocathode of the photomultiplier to eliminate image motion on the photocathode.

The spectral correction filter corrects the spectral responsivity of the photomultiplier to that of the photopic response of the human eye so that with appropriate calibration the system can make luminance measurements in terms of either candelas per meter^2 or cm^2 or footlamberts.

The electric shutter permits the computer to shut off all light for dark current averaging and subtraction. With appropriate software (all EG&G Gamma Scientific software includes this feature), a "fresh" averaged value of the dark current is developed before each series of measurements.

The schematic also shows a 4.0MHz video amplifier which may be included as an option if a separate video output is desired. It has its own separate co-axial output. This output is not required for any of the operations described in this brochure.

OPTICAL SCHEMATIC OF GS-1000 PRECISION TELESCOPE ASSEMBLY

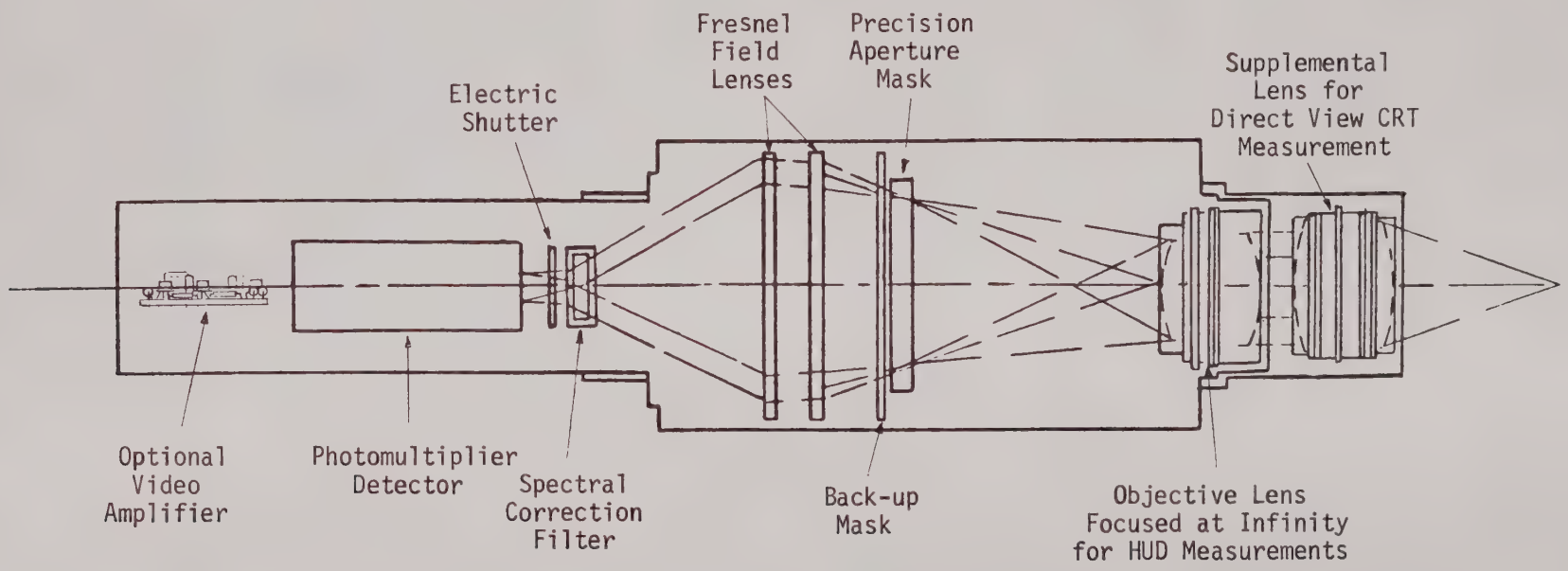


Figure 7

SYSTEM CONFIGURATION

The system hardware configuration of the GS-1000 for spatial measurements is shown in Figure 7. The precision telescope and photomultiplier detector assembly feed into the EG&G Gamma Scientific GS-4100 Intelligent Radiometer which is controlled by the desktop computer. This version of the GS-4100 has additional D to A converters to supply the special deflection signals to the CRT under test and special EPROMS to provide the machine language commands for the CRT beam motion routines. In raster scan displays a digitally programmable video blanking generator may be used if necessary for blanking out all portions of the screen except where the measurement is being made. To make measurements in various parts of the screen the blanking signal is changed so that the measurement spot is turned on at the new location and extinguished at the previously measured location.

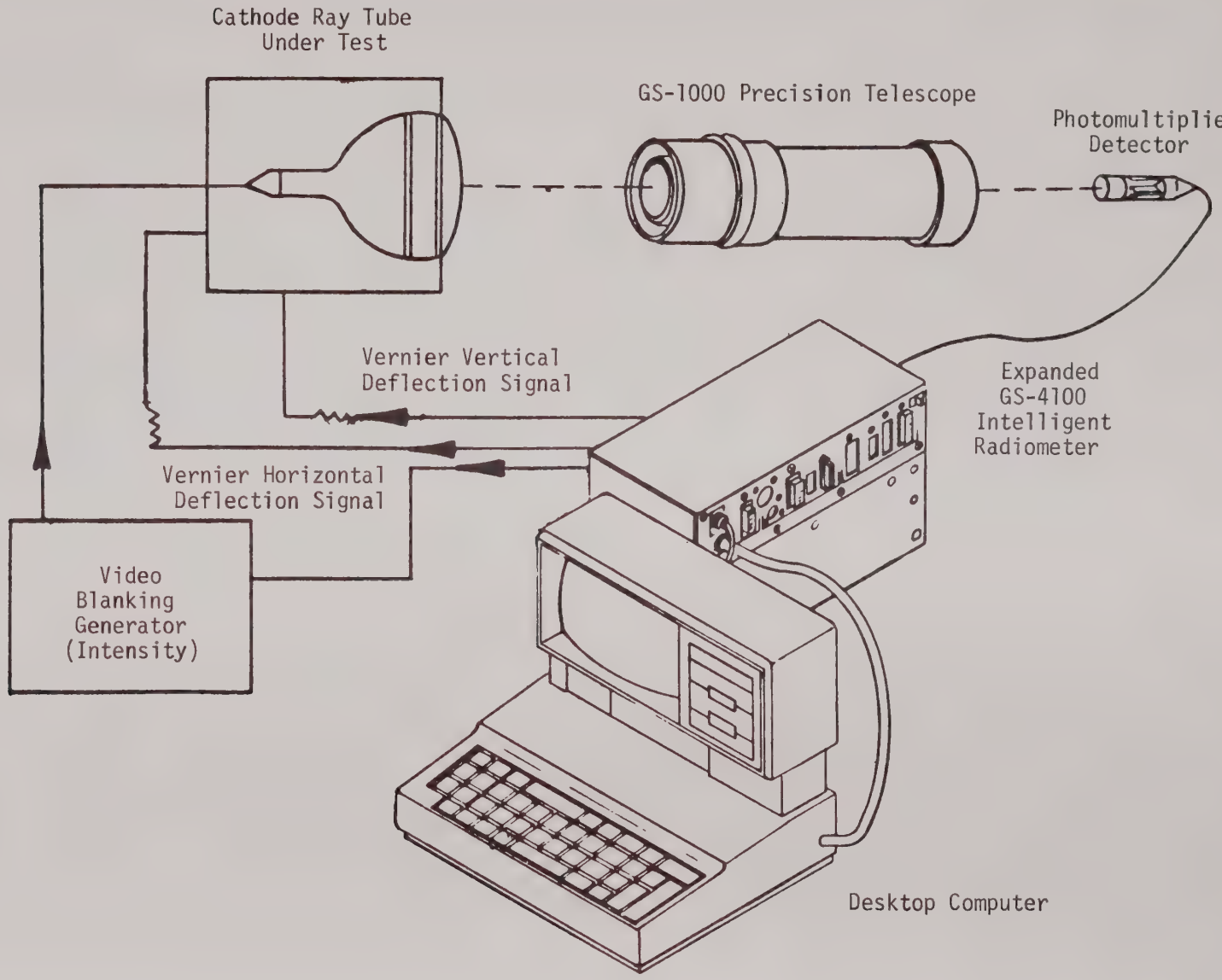

Cathode Ray Tube
Under Test
GS-1000 Precision Telescope
Photomultiplier
Detector
Vernier Vertical
Deflection Signal
Expanded
GS-4100
Intelligent
Radiometer
Vernier Horizontal
Deflection Signal
Video
Blanking
Generator
(Intensity)
Desktop Computer

Figure 8

COLOR CONFIGURATION

To add the capability of color measurement, wider apertures than those in the monochrome example must be used. The width of the aperture must be sufficient to include at least one triad of phosphor dots or strips.

Figure 9 shows the color measurement system configuration. Three separate photomultipliers are used with narrow band, red, green and blue filters so that simultaneous spatial measurements may be made on all three phosphors. This speeds the measurement and insures that there is no physical motion of the measuring system relative to the CRT during the three measurements.

The GS-4100 also is expanded to handle the signals from the three PMT's simultaneously and its EPROMS contain the special programming for the color measurement routines.

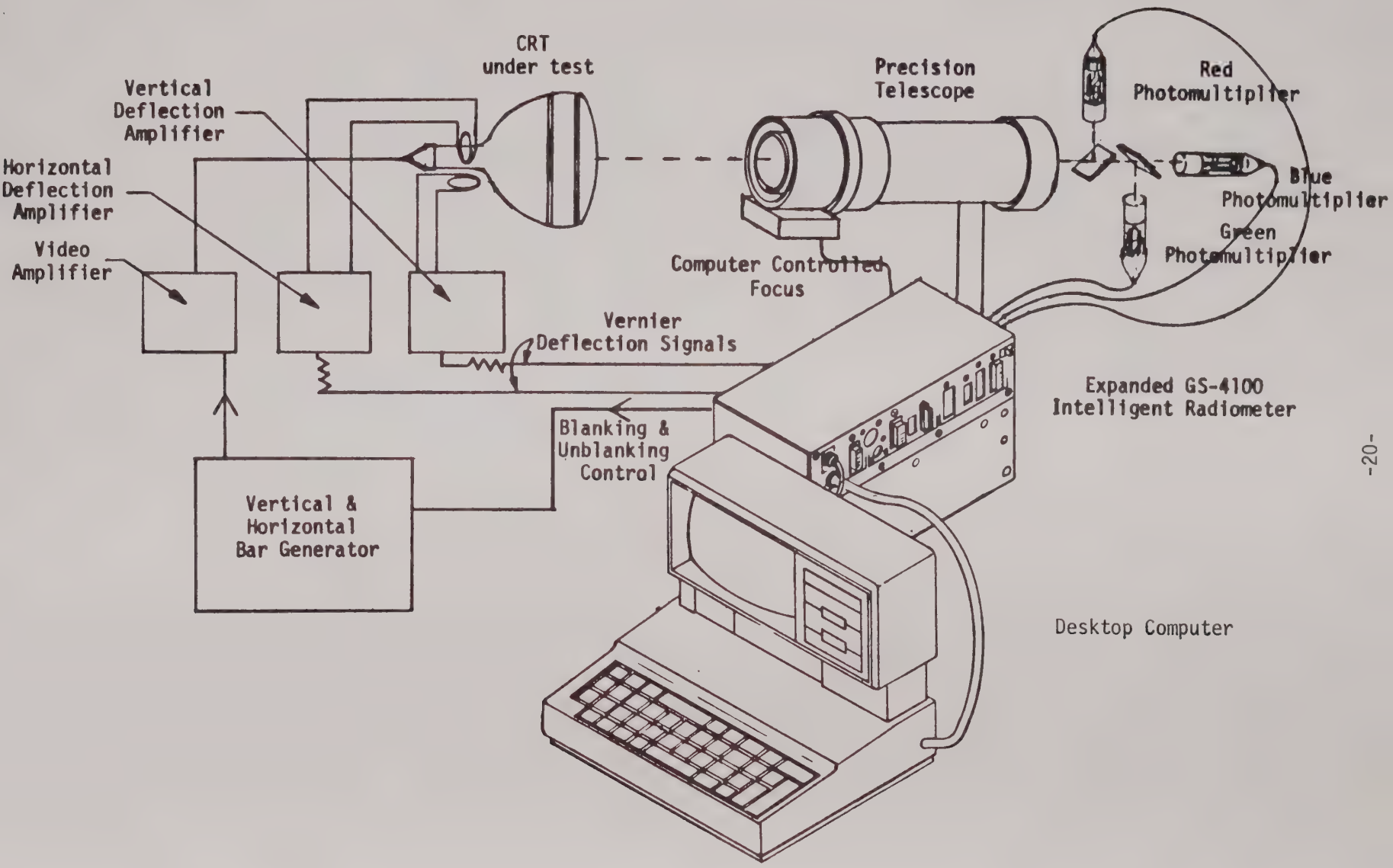

CRT
under test
Vertical
Deflection
Amplifier
Horizontal
Deflection
Amplifier
Video
Amplifier
Precision
Telescope
Red
Photomultiplier
Blue
Photomultiplier
Green
Photomultiplier
Computer Controlled
Focus
Vernier
Deflection Signals
Expanded GS-4100
Intelligent Radiometer
Blanking &
Unblanking
Control
Vertical &
Horizontal
Bar Generator
Desktop Computer

Figure 9

SYSTEM ACCURACY AND RESOLUTION

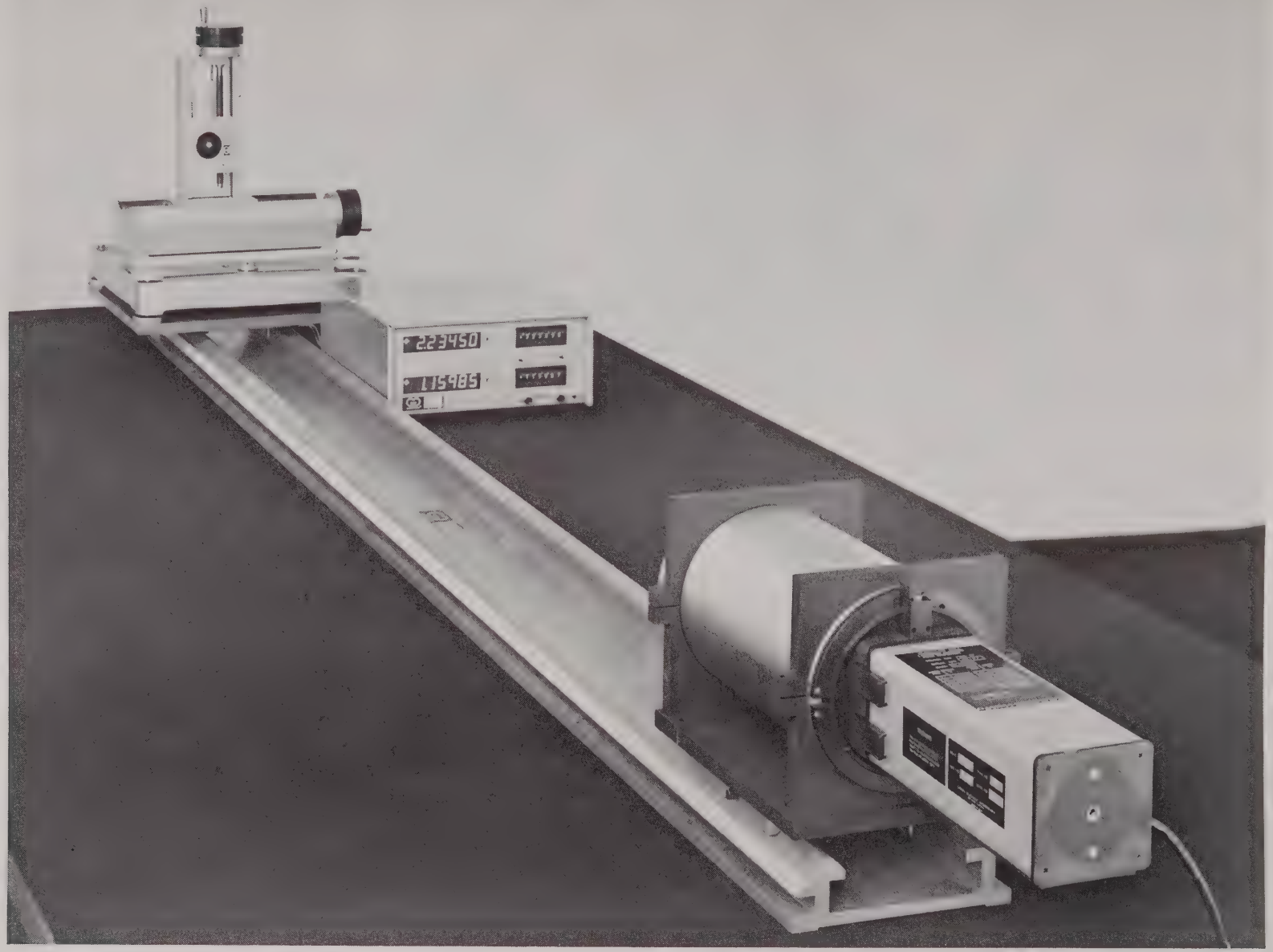
Geometric Accuracy

To measure deflection distortion (linearity) spot size and astigmatism using the technique of the GS-1000, very accurate characterization of the Precision Telescope's geometric properties is essential.

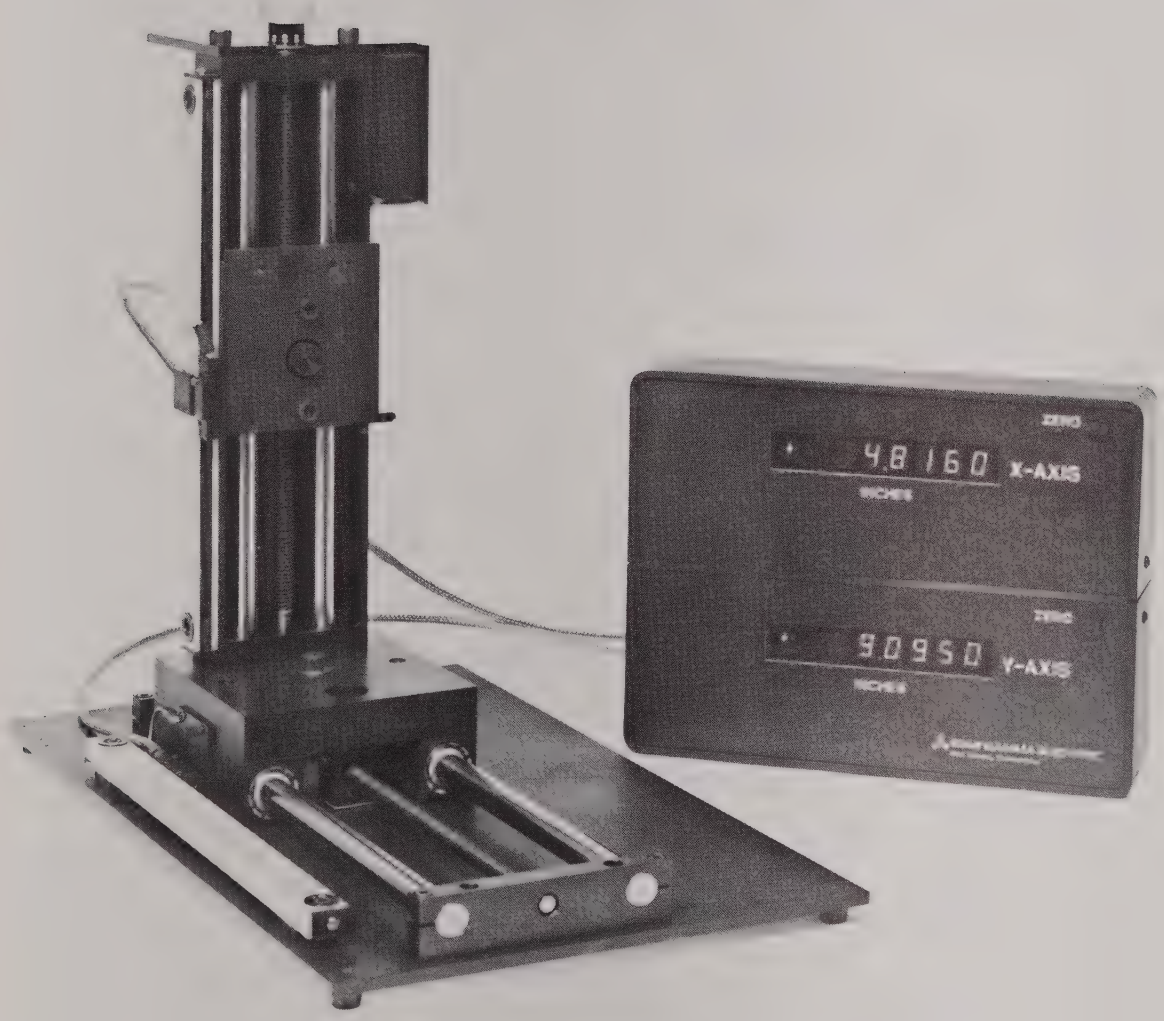
Figure 10 shows the set-up for making these measurements. A catheometer is mounted at one end of an optical bench and the GS-1000 Precision Telescope is located so that it is focused on the measurement plane of the catheometer. Mounted in the motion plane of the catheometer is a light source which simulates spectrally and geometrically a CRT spot.

During measurement the simulated CRT spot is moved until its image falls on one of the apertures of the GS-1000 Precision Telescope. By means of the catheometer X & Y controls, the light source can be moved in small increments and measurements of its intensity, as measured by the telescope versus the light source's position, can be recorded and the width and location of the aperture can be very accurately characterized. To improve the resolution of the measurement either a smaller diameter spot than the actual CRT or a narrower slit than the CRT trace may be employed. The resolution of the Gaertner Model M1236A-46 Catheometer used by EG&G Gamma Scientific, is one micron (.001mm) or one half of a ten thousandth of an inch (.00005") over a 6" X 6" area. The resolution of this catheometer is particularly important in measuring effective line width of images of the GS-1000's apertures in the phosphor plane of the CRT to be measured.

In Figure 11, a larger X-Y mechanism is shown for measuring larger distances than the catheometer in Figure 10 can cover. This mechanism is an EG&G Gamma Scientific Model GS-6010 Precision X-Y Mechanism. This mechanism,



Optical set-up for measurement of aperture locations and sizes in GS-1000 Precision Telescope. The coordinate catheometer is located in place of the phosphor screen of CRT under test. Mounted on it is a simulated CRT light source. Measurement resolution is 1 micron along each axis over a 150mm X 150mm (6" X 6") area.



EG&G Gamma Scientific Model GS-6010 Precision X Y Mechanism. Resolution is 12 microns (.0005") each axis. This mechanism covers a 10" X 10" measurement area. Readout is large size LED display. The Model GS-6010 can be used to measure larger distances than the coordinate catheometer in Figure 10.

Figure 11

which can use the same light source as the catheometer, covers a 10" X 10" area with a resolution of .0005" in both axes and an accuracy of .001". A computer controlled model with digital stepper motors on both X & Y axes is available for automated measurements.

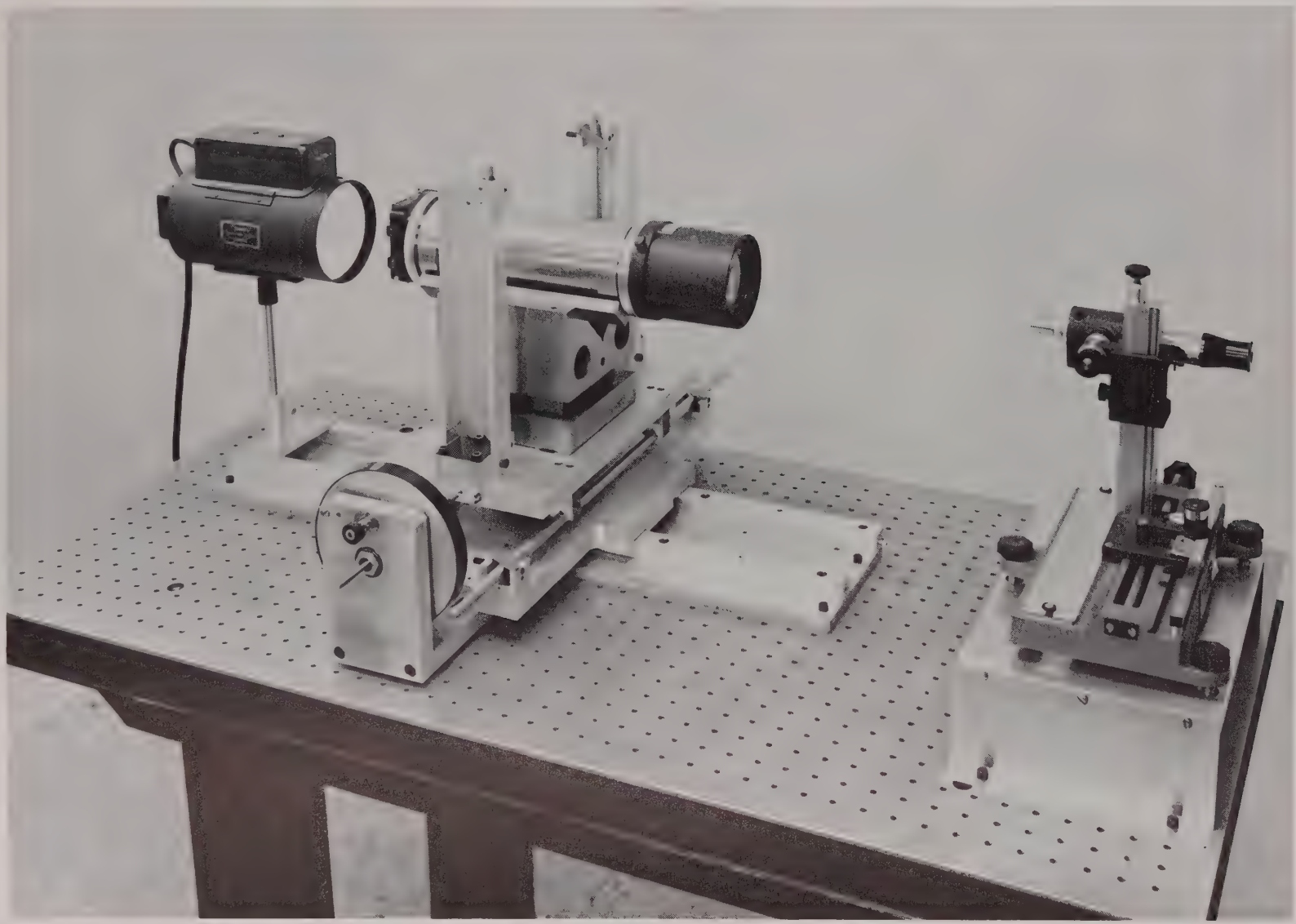
A 20" X 20" version of this mechanism, the Model GS-6020, is now under design. It will feature the same accuracy and resolution. The first delivery of this system is scheduled for mid-November, 1984.

Photometric Accuracy

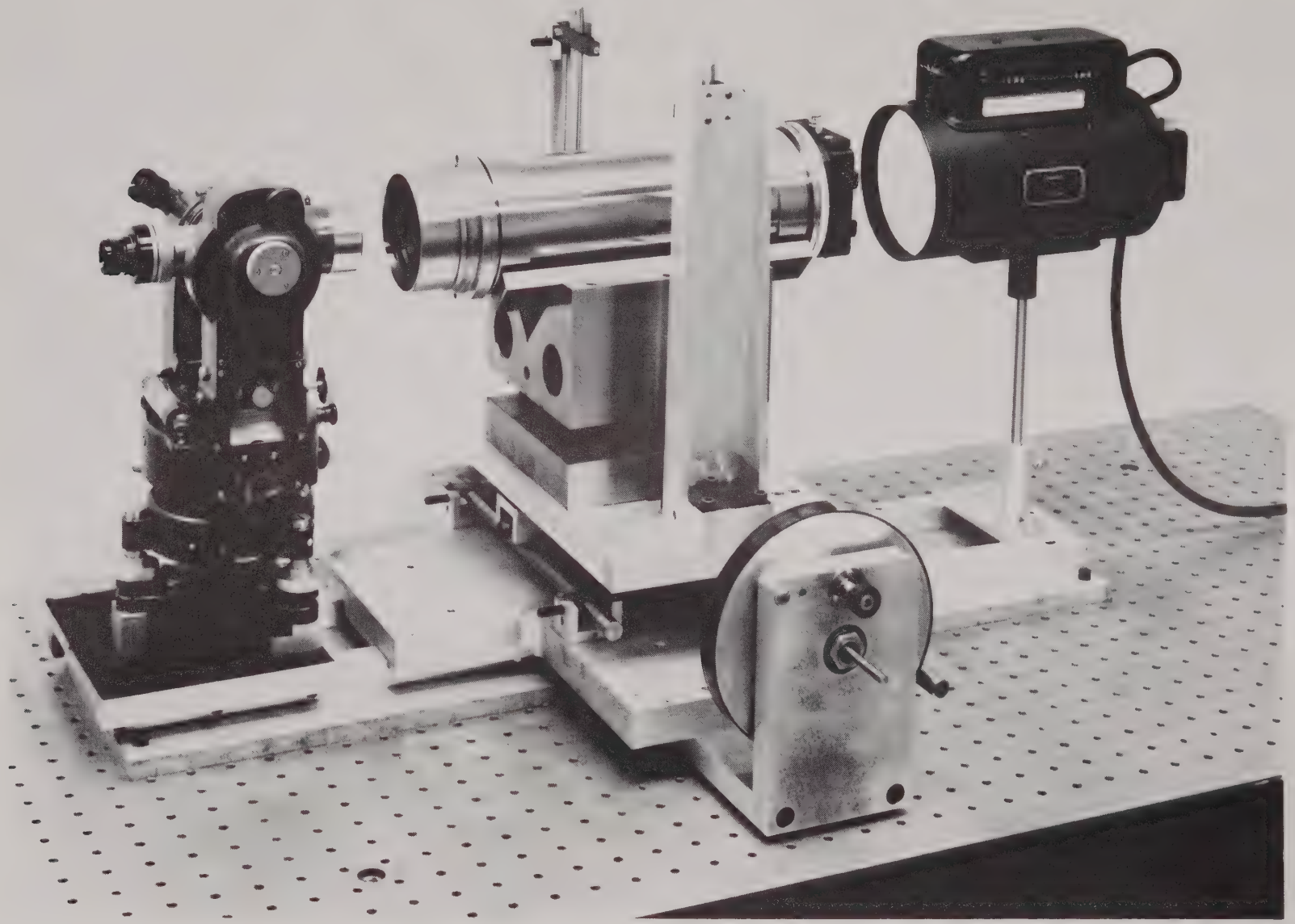
To insure the greatest photometric accuracy when the GS-1000 makes luminance measurements, a calibrated light source traceable to NBS is used to calibrate the telescope. Typically, as in the F-16, F-18, B-1B and MRCA, programs in which EG&G Gamma Scientific is currently supplying avionic display test equipment, a calibrated source is periodically mounted on the telescope. This source illuminates only the center aperture with a known luminance level. The response of the GS-1000's photomultiplier detector is then divided into the level of the calibrated source and a calibration factor is thereby developed. This correction factor is then applied by the computer to all light readings taken thru that aperture.

Correction factors for all other apertures have previously been developed at EG&G Gamma Scientific. These aperture-to-aperture correction factors are very stable and once measured, can be expected to hold to less than 1% over the long term. By applying these factors to the center aperture correction factor, all the apertures may be absolutely calibrated in terms of luminance.

Typically the calibration of the central aperture is performed once a day or less frequently depending on system absolute accuracy specifications. With such daily calibrations, absolute luminance measurements, thru the center aperture, can be made to an absolute accuracy of better than 5%, and other apertures better than 7% and a repeatability of 1 and 1-1/2% respectively.



Here a X-Y Tooling Microscope on the right measures to within 10 microns the positional accuracies of the F-16 Precision Position Detector Telescope with supplementary lens. The measurement is made in the plane of the display's phosphor screen.



Optical set-up of angular accuracy measurements of the Telescope in the GS-1000 Precision Display Measurement System. On the left a one second Theodolite (0.0048mr) looks into the telescope (center) to make the measurement. A uniform light source, on the right, evenly illuminates the aperture mask of the telescope.

TYPICAL SPATIAL SCAN DATA FROM GS-1000 SYSTEM

Measurements taken with GS-1000 System, Figures 12 and 13, show typical data taken with the GS-1000 Precision Display Measurement System.

Figure 12 shows reduced data in graphical form. Displacement in millimeters and inches are shown along the horizontal ordinate and intensity in footlamberts along the vertical. Underneath the displacement numbers the 50% width calculation and the centroid position of the trace are shown. These two calculations are done automatically by the software at the end of each scan. In this case no smoothing has been applied to the data which may be added as an option. Also, a correction for the width of the measuring slit may be applied and finally EG&G software can compute MTF if desired.

Figure 13 shows the data in tabular form. It may be operated on as mentioned above for correction and refinement or it may be stored, transmitted to another computer or printed out in the format shown.

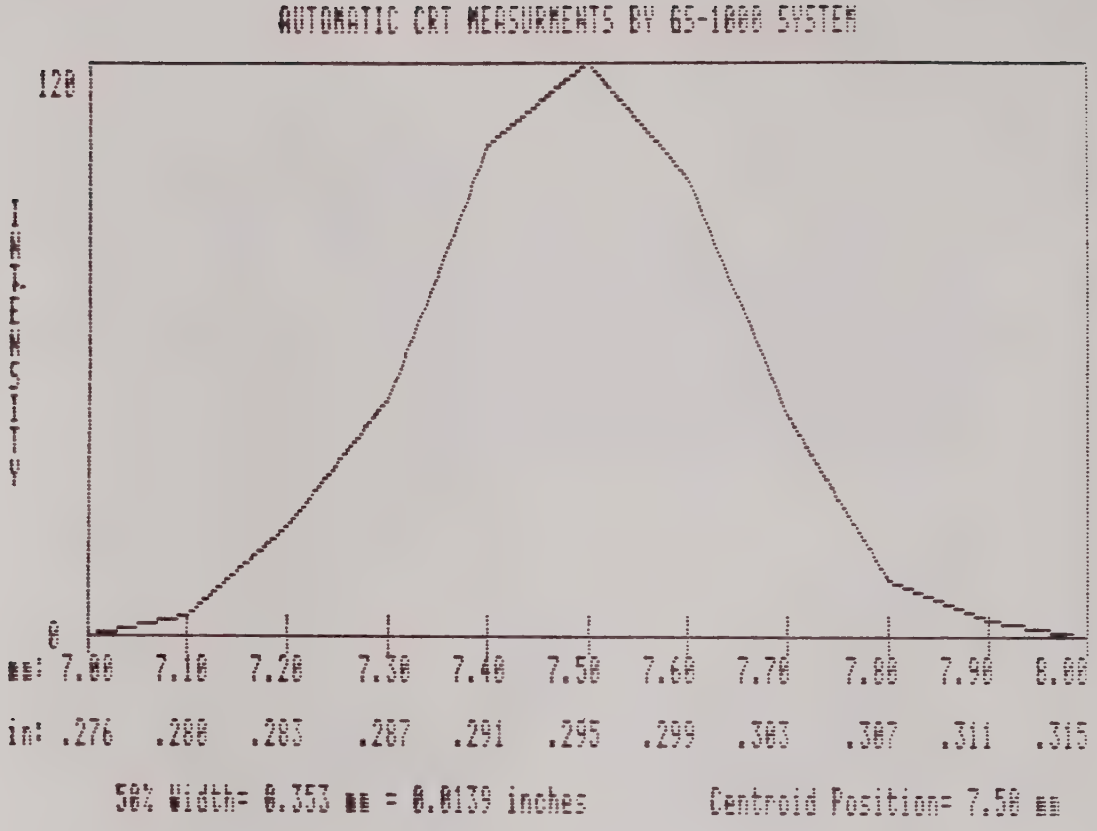


Figure 12

TABULAR DATA DISPLAY

mm's	inches	Relative Intensity	fL
0.000	0.000	0	0
0.100	0.004	3	4
0.200	0.008	19	23
0.300	0.012	41	50
0.400	0.016	85	103
0.500	0.020	100	120
0.600	0.024	80	96
0.700	0.028	39	47
0.800	0.031	10	12
0.900	0.035	2	3.6
1.000	0.039	0	0

Figure 13

September 1, 1984

GS-1000 PRECISION DISPLAY MEASUREMENT SYSTEM

SPECIFICATIONS

HEADS UP DISPLAY

PRECISION TELESCOPE/PHOTOMULTIPLIER DETECTOR ASSEMBLY

Focus:	Infinity
Focal length:	150mm nominal
Aperture:	f 5.6
Angular field of view:	30 degrees maximum
Aperture-center accuracies,	
0-4.5° from optical axis:	±0.1mr
4.5°-10° from optical axis:	±0.2mr
10°-15° from optical axis:	±0.3mr
Minimum slit aperture width:	0.066mr
Photomask design:	To customer specification
Minimum spacing between edges of adjacent apertures:	1.0 degree
Mechanical/Optical axes alignment:	±0.2 degree
Detector wavelength range:	350-930nm
with photopic filter:	380-740nm
Photopic filter accuracy:	3% nominal for illuminate "A" 2% nominal for P-1 phosphor
Internal alignment source:	Miniature tungsten lamp enabled with shutter closed
Electrical shutter:	Actuated by Radiometer
Photometric sensitivity:	0.5fL full scale on the most sensitive electrometer range 1.4mr X 1.4mr square aperture with less than a ±5% signal to noise ratio

SUPPLEMENTAL LENS FOR DIRECT VIEW CRT'S UP TO 9" DIAMETER

Focus:	43cm, 17" nominal
Focal length:	460mm nominal
Aperture:	f 9
Magnification, nominal:	0.33
Measurement area:	170mm X 170mm nominal (7" X 7")
Photometric sensitivity:	0.5fL full scale on most sensitive electrometer range for a 650 micrometer X 650 micrometer aperture (.025" X .025") with less than a ±5% signal to noise ratio
Length:	10.8cm - 4.25"
Diameter:	10cm - 4.0"
Weight:	1.2kg - 2.6"

HIGH RESOLUTION DIRECT VIEW CATHODE RAY TUBE CONFIGURATION OF PRECISION TELESCOPE/PHOTOMULTIPLIER DETECTOR ASSEMBLY

Focus:	1.6 meters
Focal length:	150mm nominal
Aperture:	f 5.6
Angular field of view:	30 degrees maximum
Measurement area:	20" x 20"
Aperture-center accuracies*,	
0-100mm from optical axis:	±0.150mm See Note 1
100 to 250mm from optical axis:	±0.300mm
250 to 375mm from optical axis:	±0.450mm
Minimum slit aperture width:	0.100mm
Photomask design:	To customer specification
Minimum spacing between edges of adjacent apertures:	25mm (in object plane)
Mechanical/Optical axes alignment:	Better than ±0.2 degree
Detector wavelength range:	350-930nm
with photopic filter:	380-740nm
Photopic filter accuracy:	3% nominal for illuminate "A" 2% nominal for P-1 phosphor
Internal alignment source:	Miniature tungsten lamp enabled with shutter closed
Electrical shutter:	Actuated through radiometer
Photometric sensitivity:	5.0fL full scale (a reading of 3800) on the most sensitive electrometer range 1.0mm X 1.0mm square aperture with less than a ±5% signal to noise ratio
Length:	55.8cm - 22.0"
Diameter:	13.9cm dia. - 5.490" dia.
Weight:	14.4kg - 31.8 lbs.
*Operating temperature:	10 to 35 degrees Celsius

NOTE 1: These specifications relate to optical accuracies within the precision telescope. By characterizing the geometric relationships of and between the telescope's apertures with a coordinate catheometer looking into the telescope, corrections to better than one part in 10^4 of the total field may be obtained.

GS-4100 INTELLIGENT RADIOMETER

Electrometer Amplifier	
Sensitivity:	1nA - 1μA full scale (10^{-12} Amps minimum resolvable current)
Range to range tracking:	±1% ±1 count
Zero drift:	±1 count after 20 minute warm-up. 0 to 50°C (after warm-up) ±.01% per °C
Dark current suppression stability:	0 to 50°C (after warm-up) ±01% per °C of full scale
Dark current suppression:	Greater than 11nA
Time constant:	100msec, 500msec, 5sec nominal, selectable from host computer
Analog output:	100mv nominal (full scale)
High Voltage	
Range:	-350 volts to -1650 volts; microprocessor controlled
Voltage variation with temperature (0 to 50°C):	±.06%/°C
Voltage monitor stability with temperature (0 to 50°C):	±.35% over whole range
Line regulation from 105V to 125V:	±.02% max. over entire voltage range
Cal Circuit (activated by microprocessor)	
Line regulation:	Better than .01%
Temperature regulation (0 to 50°):	±.01% per °C
Warm-up time:	Less than 30 seconds from turn-on. Operated by internal microprocessor
Electric Shutter	
Operation:	Microprocessor controlled
Automatic ranging:	Under microprocessor control; auto range to 1, 10, 100, 1000 nanoamperes full scale
Output:	RS-232 or IEEE-488
Power:	100 watts
Line voltage:	105/125 VAC and 210/250 VAC 50-60Hz
Temperature range:	0 to 50°C
Weight:	12.5kg - 23 lbs.
Length:	44cm - 17.5"
Height:	27cm - 10.5"
Width:	27cm - 10.5"

EG&G GAMMA SCIENTIFIC

BACKGROUND AND TECHNICAL STAFF

Gamma Scientific was founded in 1961, and since that time has had only one major commitment -- to develop and manufacture accurate advanced optical radiation measurement systems.

At the present time, over 50% of EG&G Gamma Scientific's business is based on the measurement of cathode ray tube displays. Since 1976 it has been supplying the Precision Position Detection System for angular measurement of the F-16 HUD to General Dynamics Electronics Division. Over 70 such systems have been delivered to date. Recently EG&G Gamma Scientific has received a follow-on development contract for a new design of the system to measure wide-angle holographic F-16 HUD LANTIRN displays. In 1981 EG&G Gamma Scientific received a development contract from Kaiser Electronics for a Symbol Sensor System to measure the F-18 HUD. To date it has delivered 10 systems and is expecting a follow-on of 10 more in the immediate future.

In 1981 British Aerospace placed a development and production contract for a prototype and 17 systems to measure the HUD on the MRCA Tornado Interceptor. Since that time EG&G Gamma Scientific has received a follow-on contract for and delivered 8 additional systems.

This specific experience in producing systems to measure military HUD's to angular accuracies of plus/minus 0.1 milliradian in computer controlled systems, gives EG&G Gamma Scientific the depth to design the GS-1000 precision automatic photometric/spatial measurement system.

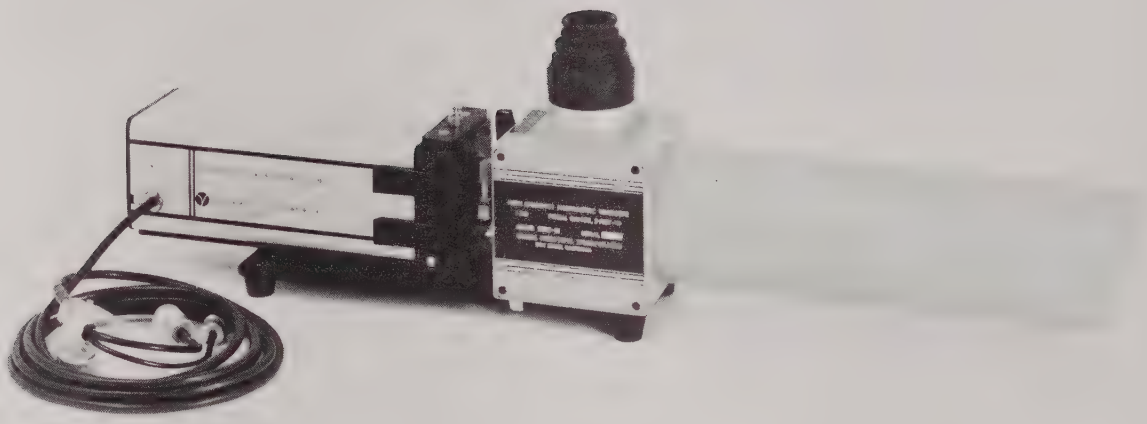
Besides this HUD measurement experience, Gamma Scientific, since 1976, has delivered 225 computer controlled scanning systems for optical radiation

analysis. In its engineering department it has its own software engineering section with three full-time engineers. Its electronic engineering section contains senior analog, digital, and firmware engineers. There is also a mechanical design and documentation section and a senior optical physicist. In addition, it has as a consultant, Justin J. Rennilson, who served as Gamma Scientific's Vice President of Research and Engineering from 1974 to 1982.

EARLIER DESIGNS

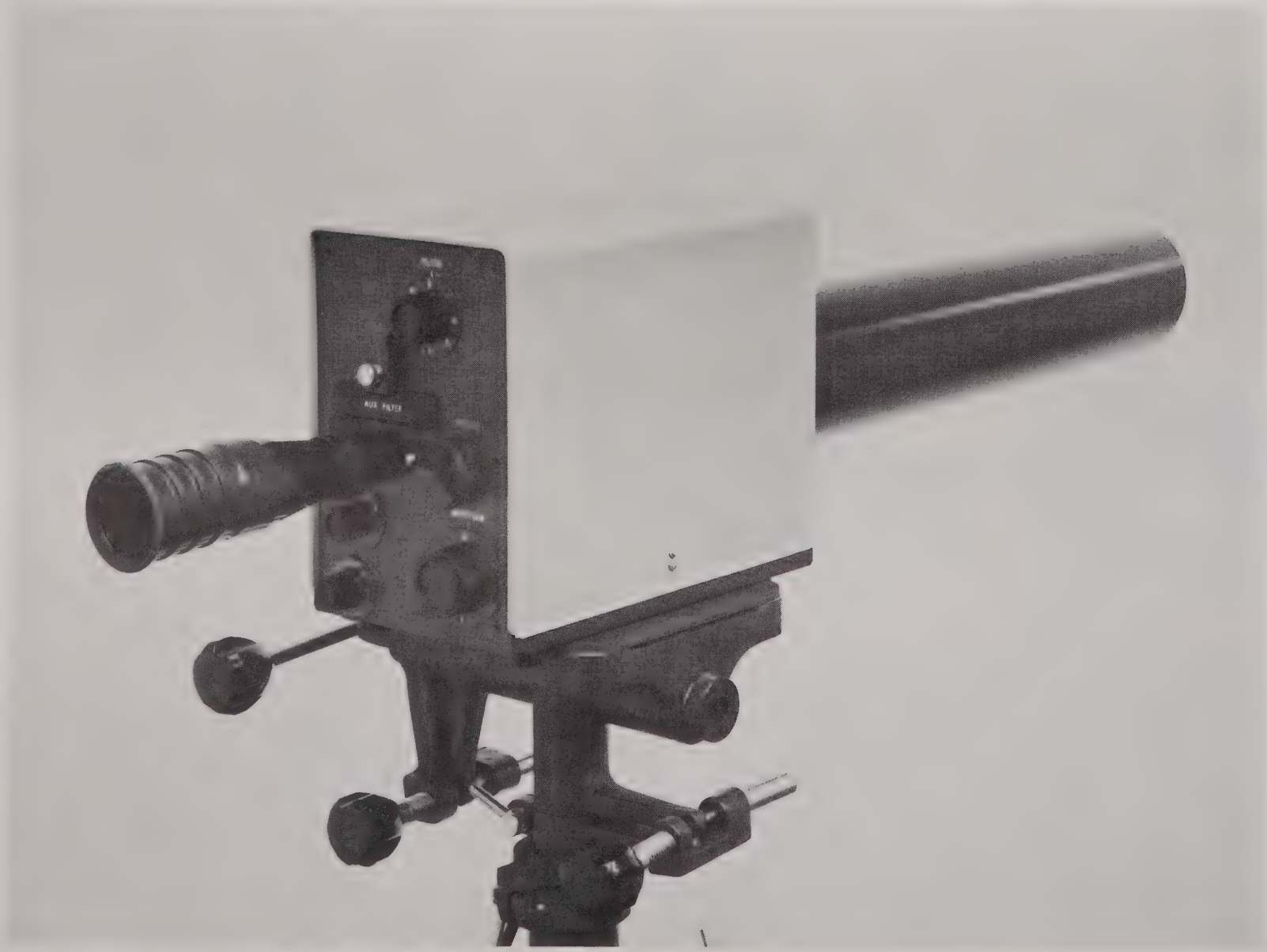
In addition to the production hardware previously mentioned for use in major avionics programs, EG&G Gamma Scientific has also built and delivered, in the 1974-1978 period, a number of special high resolution systems for measuring the output of heads-up displays.

The following pages show some of those designs.

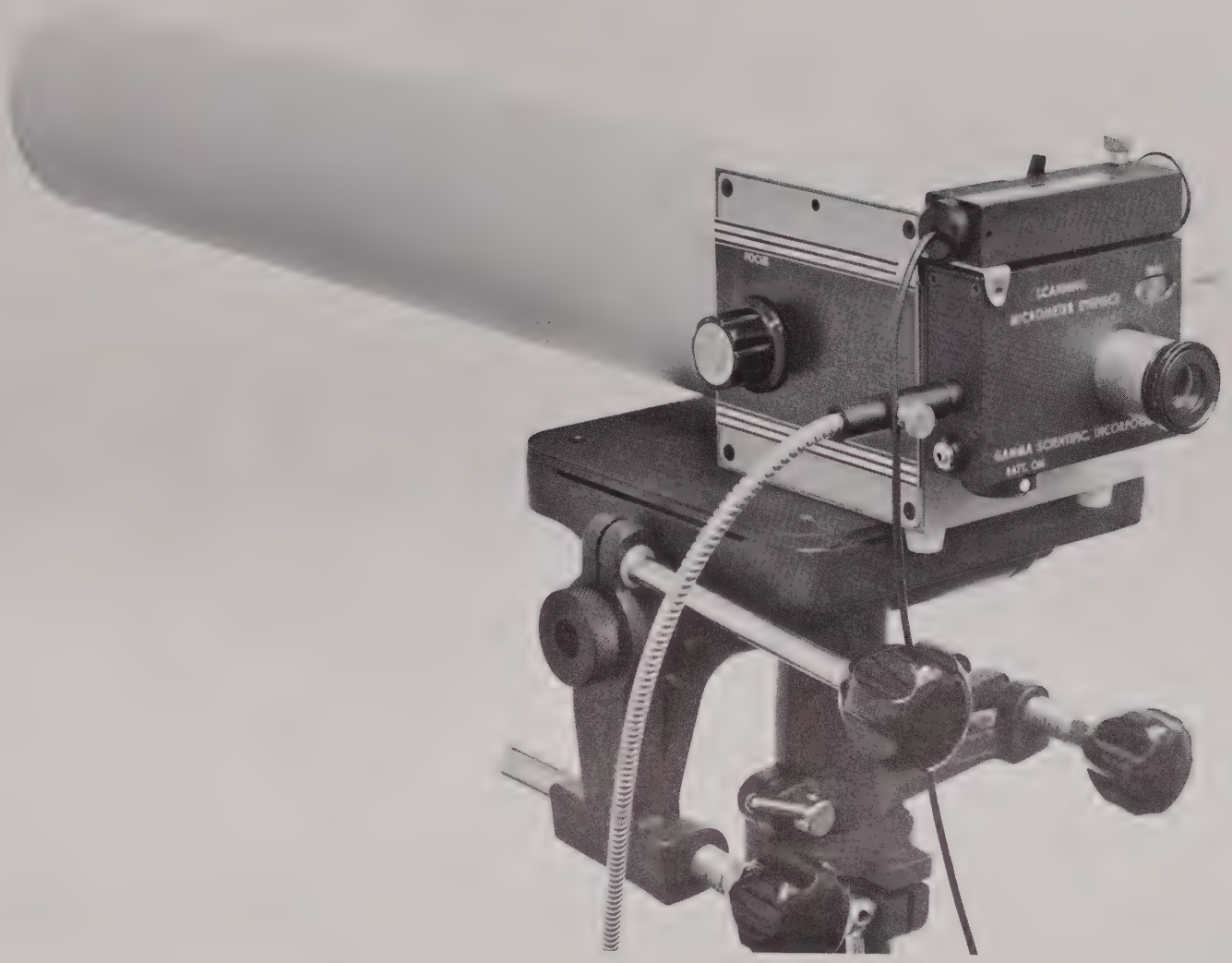


Early (1973) Gamma Scientific 2020-31SMR Telephotometer Head with single 0.3mr aperture coupled to 2020-1 Detector Assembly with S-11 Photomultiplier Tube.

First Gamma Scientific 2009 SMR Telephotometer (1974) with selectable 0.1, 0.3, 1.0 3.0 and 10mr apertures.



Current Gamma Scientific 2009, SMRJ Telephotometer specifically designed for 0.1mr resolution in HUD applications using a 500mm focal length lens.



Current Gamma Scientific 2020-31SMR Telephotometer Head with 0.1mr aperture and scanning head for scanning a 1.0mr image and developing displacement versus intensity outputs for x, y plot of the luminance profile of the image.

Present day products of EG&G Gamma Scientific for measuring spatial, luminance and color characteristics of electronic displays.

EG&G GAMMA SCIENTIFIC

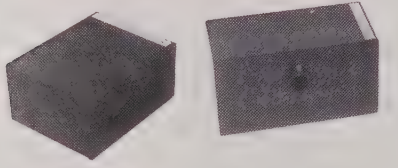
Systems for the Measurement
of Optical Radiation

SELECTION GUIDE

SUMMARY CATALOG
Major Assemblies

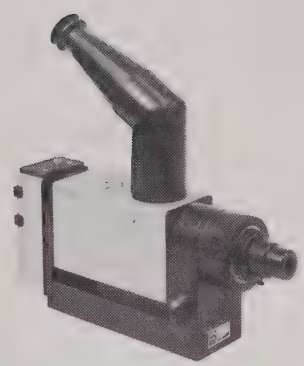
Wide Spectral Range Detectors
Interchangeable photomultiplier (D-46AQ) and silicon (D-60) detectors cover the spectral range from 200 nm to 1.1μm. Ambient or cooled; magnetically and electrostatically shielded. Inputs couple to any EG&G Gamma Scientific spectral selector or receptor. Photopic and scotopic filters available.

DR Series Digital Radiometers
DR-1A, DR-2, DR-2D
3½-digit high sensitivity electrometer with programmable exponents, plus stable high voltage supply variable from 350 to 1650V. Compatible with all EG&G Gamma Scientific photomultiplier and silicon detector assemblies and CR-15 Electric Shutter. Analog and BCD outputs.
DR-1A has manual ranging, 2 conversions/sec.
DR-2 has auto ranging, 10 conversions/sec.
DR-2D has auto ranging, 100 conversions/sec.



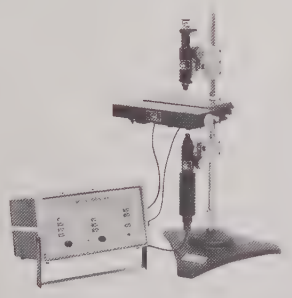
NM-3,5,7,9 Holographic Grating Monochromators
Wide spectral range from 300nm-1.1μm (NM-3, NM-7) or 200-800nm (NM-5, NM-9) without changing grating. Motor driven for use with any SC-series or GS-4100 Scanning Control. Extremely low stray light. Aberration-corrected f3.5 gratings, single in NM-3, NM-5, dual in NM-7, NM-9. Half-power bandwidths 6,4,3 and 2nm respectively.

700-10C Photometric Microscope
Versatile, stable receptor with interchangeable objectives and eyepieces, X-Y positioning control, 10° tangent vernier for eyepiece aperture adjustment, coarse and vernier focusing controls. Eyepieces couple to detectors via 700-3 series fiber optic probes.

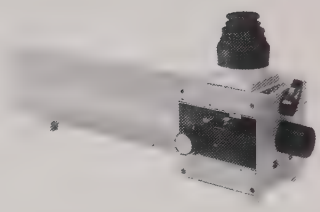


GS-2110A
Radiometric Telemicroscope System
High performance spatial/spectral scanning system specifically designed for computer-controlled operation. Straight-thru optics with swing-away viewing system maximizes thruput, is easily aligned and focused, and ensures negligible polarization. Couples to any NM-Series monochromator and/or EG&G Gamma Scientific detector.

SC-1,2,4,5 Scanning Controls
Provide power, readout and control functions for all motor drive scanning systems, including scanning photometric eyepieces, microdensitometer scanning stages, telemicroscope apertures and monochromators. SC-1 drives dc motors in manually controlled scanning systems, has 10-turn variable speed and fast slew/scan controls, BCD outputs. SC-2 and SC-4 drive dc motors and have parallel and serial interfaces, respectively, for computer control. The SC-5 controls digital stepping motor drives in the GS-2110A Telemicroscope and NM-series monochromators equipped with option 6.

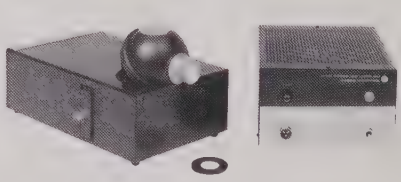


700-10-90 Scanning Microdensitometer
Includes illuminating and collecting microscopes with a flat-top scanning stage, ring light, stand, and control unit. Stage has 60x150mm manual scanning area, with selectable motor driven scan lengths on the X axis of 5, 25 or 100mm. Log converter allows direct presentation of density. Reflection density measurements can be made with 700-10-90-13 conversion.

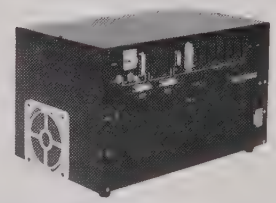


2020-31 Series High Efficiency Photometric Telescopes
Apertures of 6′, 20′, 1° and 3° selectable by rotary switch, with 64mm diameter, 190mm effective focal length lens. Field of view is 15°, focusing 1 ft. to infinity or 3 ft. to infinity. Directly compatible with NM-series monochromators.

191C Gonioreflectometer Head
Includes tungsten-halogen illumination microscope and collection microscope with integrating cavity. Analysis area is 0.25x0.76mm; measurement area 2.5x1.78mm. Angle between microscopes adjustable from 20° to 100°. Optics designed for curved, sloped or parallel surfaces. Couples to detectors or monochromators via 700-3 series fiber optic probes.



GS-5100 Diffuse Reflectance/Transmittance Head
Extends spectral range of reflectance measurements to 200-1100nm by using deuterium and tungsten-halogen lamps in a combined optical system. Measurement geometry for spectral reflectance uses 10° illumination with either specular reflectance included (SIN) or specular reflectance excluded (SEX). Source projection optics are included.



GS-4100 Intelligent Radiometer
Microprocessor-controlled with automatic dark current, zero, scaling, HV settings, reference amplitude correction. No adjustments, controls or displays. Includes scan control for digital drive scanning systems. Serial interface to host computer, to 9600 baud.

EG&G GAMMA SCIENTIFIC
3777 RUFFIN ROAD, SAN DIEGO, CALIFORNIA 92123
TEL (619) 279-8034

EG&G GAMMA SCIENTIFIC

Model GS 4100
Intelligent Radiometer

FEATURES

The First Radiometer with No Controls

Internal microprocessor controlled:

- ☐ **Electronic dark current suppression**
- ☐ **Zero offset subtraction**
- ☐ **Autoranging decisions**
- ☐ **Signal Averaging**
- ☐ **Self-calibration of:**
  Wavelength scale (Spectral)
  Displacement scale (Spatial)
  Amplitude scale
- ☐ **Variable scan intervals**
- ☐ **Setting photomultiplier high voltage**
- ☐ **Selection of amplifier time constant**
- ☐ **Linearity correction over total amplifier dynamic range**
- ☐ **Amplitude correction based on internal reference lamp**
- ☐ **Shutter and filter insertion**

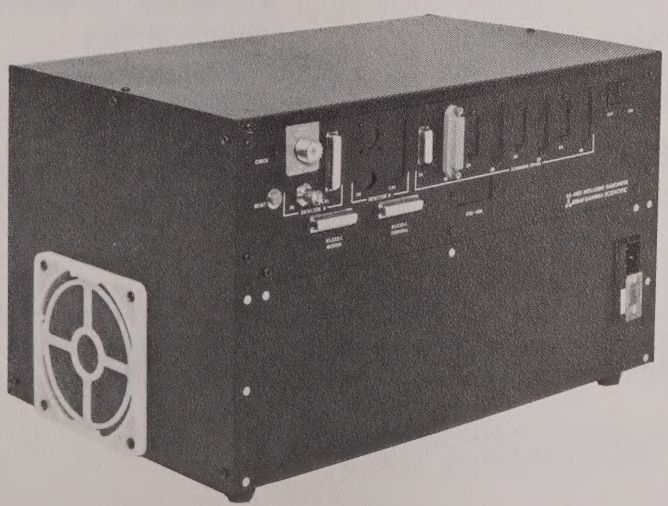
The GS 4100 Intelligent Radiometer with its own microprocessor represents a brand new concept in instrumentation for optical radiation measurements. It has no adjustments—no dark current, no zero and high voltage controls, no range switches, no displays, no indicators, no calibration controls and no shutter and time constant selection switches. It is simply a black box with an on/off control.

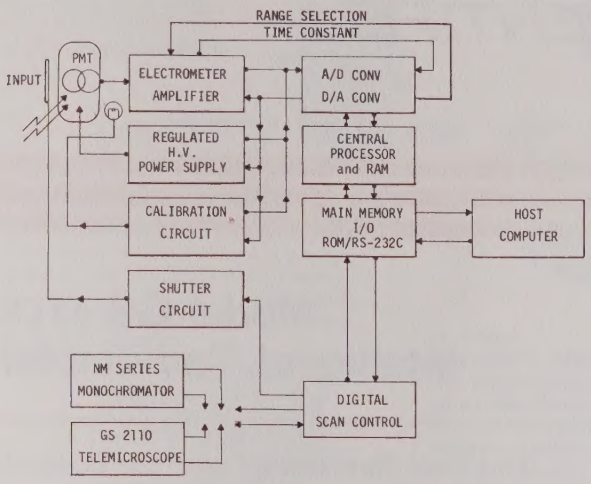
The GS 4100 has been under development for three years by Gamma Scientific hardware and firmware engineers. It reflects Gamma Scientific's extensive computer experience and represents the current state-of-the-computer-art.

The GS 4100 can be controlled by any host computer via a two-way RS-232 interface at rates up to 9600 baud. Desktop computers as small as the HP 85 can operate the GS 4100.

It is designed to work with any of Gamma Scientific's detector assemblies, both photomultiplier and silicon.

Included in the GS 4100 is complete logic and control circuitry for spectral and spatial scanning applications. It will operate any of Gamma Scientific's NM Series of Digital Holographic Monochrpmators or its new GS 2110 Digital Scanning Telemicroscope.





BLOCK DIAGRAM OF GS 4100 INTELLIGENT RADIOMETER

The block diagram to the left shows the main elements of the GS 4100. By combining radiometer, microprocessor and scanning control together, the microprocessor can perform more functions more efficiently and can simplify combined operations such as scanning and autoranging.

Functionally, the intelligent radiometer contains an electrometer amplifier, a high voltage power supply, and A/D and D/A converter, and a Z80 Microprocessor with 8K of ROM for its firmware. This firmware is in machine code so that its operation is very fast, this in turn, speeds up system operation. In addition the digital scan control, calibrator and shutter control circuits are included.

A simplified command structure allows the GS 4100 to be easily and rapidly controlled by the host computer. Because all radiometer functions are included in this command structure, the host computer's software can tailor test routines to any specialized measurement requirements.

PRELIMINARY TECHNICAL SPECIFICATION

ELECTROMETER AMPLIFIER

Sensitivity: 1nA full scale , most sensitive range (±4096 counts of resolution)

Linearity (Single Range): ±0.1% ±1 count.

Zero Drift: ±1 count after 20 minute warm-up. 0 to 50°C (after warm-up) ±.01% per °C. Normalized by internal microprocessor.

Dark Current Suppression: Greater than 11nA. Controlled and normalized by internal microprocessor.

Dark Current Suppression Stability: 0 to 50° (after warm-up) ±.01% per °C of full scale.

Time Constant: 10 msec, 50 msec, 1 sec nominal. Microprocessor selectable.

Automatic Ranging: Under microprocessor control. 4 electrometer ranges, 1, 10, 100, 1000 nanoamperes full scale.

HIGH VOLTAGE

Range: 350 volts to 1650. Controlled by internal microprocessor.

Voltage Variation with temperature (0 to 50°C): ±.06%/°C.

Voltage Monitor Stability with temperature (0 to 50°C): ±.35% over whole range.

Line Regulation from 105V to 125V:
@ 350 volts ±.02% max.
@1650 volts ±.02% max.

MICROPROCESSOR

CPU: Z80A

Memory: RAM 1K
ROM 8K

Clock Rate: 2mHz

I/O: RS 232C using AM 9551 communications IC

Baud Rate: 110 to 9.6K

CAL CIRCUIT

Line Regulation: Better than .01%.

Temperature Regulation (0 to 50°): ±.01% per °C.

Warm-up Time: Less than 30 seconds from turn on. Operated by internal microprocessor.

ELECTRIC SHUTTER

Microprocessor controllable.

GENERAL

Line Voltage: 105/125 VAC and 210/250 VAC 50-60 Hz.

Power: 100 Watts

Temperature Range: 0 to 50°C.

Weight: 15 lbs.

Length: 18″

Height: 10″

Width: 10½″

EG&G GAMMA SCIENTIFIC

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